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Transmitted herewith for filing is the patent application of

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Takatoshi Mayama

For: LIQUID CRYSTAL DISPLAY DEVICE
OPERATING IN A VERTICALLY
ALIGNED MODE OF LIQUID CRYSTAL
MOLECULES

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Enclosed are:

- (X) 24 pages of specification, including 5 claims and an abstract.
- () an executed oath or declaration, with power of attorney.
- (X) an unexecuted oath or declaration, with power of attorney.
- (X) 8 sheet(s) of informal drawing(s).
- () sheet(s) of formal drawings(s).
- () Assignment(s) of the invention to _____.
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Fee Calculation For Claims As Filed

a) Basic Fee						\$760.00
b) Independent Claims	<u>2</u>	-	<u>3</u>	=	<u>1</u>	x \$ 78.00 = \$ <u>78.00</u>
c) Total Claims	<u>5</u>	-	<u>20</u>	=	<u>0</u>	x \$ 18.00 = \$ _____
d) Fee for Multiple Claims						\$260.00 = \$ _____
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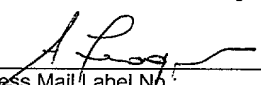
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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Seiji Tanuma, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Yohei Nakanishi, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan and Takatoshi Mayama, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan have invented certain new and useful improvements in

LIQUID CRYSTAL DISPLAY DEVICE OPERATING IN A
VERTICALLY ALIGNED MODE OF LIQUID CRYSTAL MOLECULES

of which the following is a specification : -

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1 TITLE OF THE INVENTION

LIQUID CRYSTAL DISPLAY DEVICE OPERATING IN A
VERTICALLY ALIGNED MODE OF LIQUID CRYSTAL MOLECULES

5 BACKGROUND OF THE INVENTION

The present invention generally relates to
liquid crystal display devices and more particularly
to a high-contrast liquid crystal display device
characterized by a fast response speed and a low
10 electric power consumption.

FIG.1 shows the construction of a
conventional liquid crystal display device of the so-
called TN-mode.

Referring to FIG.1, the conventional liquid
15 crystal display device includes a glass substrate 2a
carrying thereon a number of active devices including
pixel electrodes 6 and cooperating bus lines 5,
wherein the glass substrate 2a faces a glass substrate
2b carrying thereon an opposing electrode 3, with a
20 liquid crystal layer 1 interposed between the glass
substrate 2a and the glass substrate 2b. It should be
noted that the glass substrate 2a further carries a
molecular alignment film 4 so as to cover the
foregoing active devices, while the glass substrate 2b
25 carries another molecular alignment film 5 so as to
cover the opposing electrode 3.

In the conventional structure of FIG.1, a
liquid crystal called TN (twist-nematic) type is used
commonly for the liquid crystal layer 1. In such a
30 conventional, TN-mode liquid crystal display device
using a TN-type liquid crystal, the liquid crystal
molecules are aligned generally parallel to the plane
of the substrates in the non-activated state thereof
in which no drive voltage is applied to the liquid
35 crystal layer. In the non-activated state, the liquid
crystal molecules are further twisted between the
substrate 2a and the substrate 2b with a twist angle

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1 of 90°. When a drive voltage is applied to the liquid
crystal layer 1, on the other hand, the liquid crystal
molecules are aligned generally perpendicular to the
plane of the substrates 2a and 2b.

5 Such a TN-mode liquid crystal display device
is used commonly in various information processing
apparatuses. Further, low-cost fabrication process of
such a TN-mode liquid crystal display device is well
established by now.

10 On the other hand, a TN-mode liquid crystal
display device generally has a drawback in that the
contrast ratio of represented images changes
substantially depending on the viewing angle. While
there are various attempts to improve the viewing
15 angle characteristic of TN-mode liquid crystal display
devices, it has been still difficult to realize a
viewing characteristic comparable to that of a CRT
display device.

20 On the other hand, there is another type of
liquid crystal display device in which the liquid
crystal molecules are aligned generally
perpendicularly to the plane of the glass substrate.
In such vertically aligned liquid crystal display
devices, the liquid crystal molecules are aligned
25 generally perpendicular to the plane of the glass
substrates in the non-activated state.

FIGS.2A and 2B show the construction of one
type of such a vertically aligned liquid crystal
display device.

30 Referring to FIG.2A showing a pixel of such
a vertically aligned liquid crystal display device in
the non-activated state thereof, the liquid crystal
display device includes a first glass substrate 10
carrying thereon a pair of electrodes 11a and 11b and
35 a second glass substrate 12 facing the first glass
substrate 10, and a liquid crystal layer 14 is
sandwiched between the glass substrate 10 and the

1 glass substrate 12. In the non-activated state of the
liquid crystal display device, it should be noted that
no drive voltage is applied across the electrodes 11a
and 11b.

5 The liquid crystal layer 14 includes liquid
crystal molecules 16, wherein the liquid crystal
molecules 16 are aligned generally perpendicularly to
the plane of the substrate 10 in the non-activated
10 state of the liquid crystal display device represented
in FIG.2A. It should be noted that the surface of the
substrate 10 on which the electrodes 11a and 11b are
provided is covered by a molecular alignment film not
illustrated. Similarly, the surface of the substrate
12 facing the liquid crystal layer 14 is covered by a
15 molecular alignment film not illustrated. Further, a
pair of polarizers not illustrated are disposed at
respective outer-sides of the glass substrate 10 and
the glass substrate 12.

In the activated state represented in FIG.2B
20 in which a drive voltage is applied across the
electrodes 11a and 11b, on the other hand, the liquid
crystal molecules 16 are aligned in the direction of
the electric field inside the liquid crystal layer 14.
Thereby, the pixel represented in FIG.2B is divided
25 into a first region at a first side of a line A-A' and
a second region at a second, opposite side of the line
A-A', wherein it can be seen that the liquid crystal
molecules 16 are tilted in respective, mutually
opposite directions in the first region and in the
30 second region. As a result of such a subdivision of
the pixel, the liquid crystal display device provides
an excellent viewing angle characteristic.

On the other hand, the vertically aligned
liquid crystal display device of FIG.2 has a drawback
35 in that it requires a drive voltage of at least 5 V.
In order to reduce the power consumption of the liquid
crystal display device, it is desired to reduce the

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1 drive voltage.

In a liquid crystal display device, the drive voltage is generally reduced by increasing the retardation value $\Delta n \cdot d$, wherein Δn represents the
5 birefringence and d represents the cell thickness. On the other hand, there has been little information about the optimum value for the birefringence Δn or for the cell thickness d in this type of the vertically aligned liquid crystal display devices.

10 Further, this type of vertically aligned liquid crystal display devices have conventionally suffered from the problem of poor response speed. This drawback becomes particularly conspicuous when performing a motion picture representation.

15

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful liquid crystal display device wherein the foregoing problems
20 are eliminated.

Another object of the present invention is to provide a liquid crystal display device, comprising:

- 25 a first substrate;
- a second substrate facing said first substrate;
- a liquid crystal layer interposed between said first and second substrates; and
- a group of electrodes disposed on said first
30 substrate so as to create an electric field in said liquid crystal layer generally parallel to said first substrate in an activated state in which a drive voltage is applied to said group of electrodes;
- said liquid crystal molecules aligning
35 generally perpendicularly to a plane of said first substrate in a non-activated state in which said drive voltage is not applied to said group of electrodes,

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1 said liquid crystal molecules aligning generally
parallel to said plane of said first substrate in said
activated state;

5 said liquid crystal molecules having a pre-
tilt angle of less than 90° in at least one of a part
of said liquid crystal layer corresponding to a pixel
and said electrode on said first substrate.

10 According to the present invention, the
response speed of the liquid crystal display device is
improved by locally setting the pre-tilt angle of the
liquid crystal molecules to be less than 90° .
Thereby, such pre-tilted liquid crystal molecules act
as a nuclei when a drive electric field is applied to
the liquid crystal layer, and the tilting of the
15 liquid crystal molecules propagates rapidly throughout
the liquid crystal layer, starting from such a site of
the pre-tilted molecules. Associated with this, the
drive voltage of the liquid crystal display device is
reduced, and hence the electric power consumption.

20 Other objects and further features of the
present invention will become apparent from the
following detailed description when read in
conjunction with the attached drawings.

25 BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 is a diagram showing the construction
of a conventional TN-mode liquid crystal display
device;

30 FIGS.2A and 2B are diagrams showing the
construction of a conventional vertically aligned
liquid crystal display device respectively in a non-
activated state and in an activated state thereof;

35 FIG.3 is a diagram showing the principle of
the liquid crystal display panel of the present
invention;

FIG.4 is another diagram showing the
principle of the liquid crystal display panel of the

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FIG.5 is a diagram showing the construction of a liquid crystal display device according to a first embodiment of the present invention;

FIG.7 is a diagram showing the construction of a liquid crystal display device according to a third embodiment of the present invention;

FIG.9 is a diagram showing the construction
15 of a liquid crystal display device according to a
fifth embodiment of the present invention.

20 First, the principle of the present
invention will be explained with reference to FIG.3
and FIG.4, wherein those parts corresponding to the
parts described previously are designated by the same
reference numerals and the description thereof will be
25 omitted.

35 According to a first aspect of the present
invention, the liquid crystal molecules are easily
tilted in the pre-tilt direction when the drive

Referring to FIG.5, the liquid crystal display device 30 includes a first glass substrate 32

1 carrying thereon electrodes 34 and 36, wherein it
should be noted that the electrodes 34 and 36 carry
thereon organic projections 38 and 39 respectively.
Further, the first glass substrate 32 is covered by a
5 molecular alignment film 42 such that the molecular
alignment film 42 covers the electrodes 34 and 36 and
further the projections 38 and 39. Further, another
molecular alignment film 44 covers the surface of a
second glass substrate 33. The first glass substrate
10 32 and the second glass substrate 33 are disposed such
that a liquid crystal layer 50 is sandwiched
therebetween. Thereby, the molecular alignment films
42 and 44 restrict the direction of the liquid crystal
molecules in the liquid crystal layer 50 such that the
15 liquid crystal molecules are aligned generally
perpendicularly to the plane of the substrate 32 or 33
in the non-activated state of the liquid crystal
display device 30. In other words, the molecular
alignment films 42 and 44 are vertically aligning
20 molecular alignment films.

The liquid crystal display device 30 of
FIG.5 is fabricated according to the process as
follows.

First, the electrodes 34 and 36 are formed
25 on the first glass substrate 31 by a patterning
process of a conductor layer such that each of the
electrodes 34 and 36 has a width W of $5\ \mu\text{m}$ and such
that the electrodes 34 and 36 are separated from each
other by a mutual separation L of about $12\ \mu\text{m}$.

30 Next, the projections 38 and 39 are formed
respectively on the electrodes 34 and 36 in the form
of a resist pattern having a height h of about $1.5\ \mu\text{m}$.
After applying a thermal curing process to the resist
pattern thus formed at the temperature of about 120°C
35 for about 30 minutes, each of the projections 38 and
39 undergoes a reflowing, and the resist projections
38 and 39 are transformed to have a bell-shaped form.

In view of the nature of the vertically aligning molecular alignment film 42, it should be noted that the liquid crystal molecules maintain a generally vertical relationship with respect to the molecular alignment film 42, including the liquid crystal molecules 50a and 50b that are located adjacent to the projection 38 or the projection 39. Thereby, the liquid crystal molecule 50a or 50b form an oblique, pre-tilt angle 51 with respect to the substrate 32, wherein it should be noted that the direction of the pre-tilt angle 51 is identical with the general direction of tilting of the liquid crystal molecules when a drive voltage is applied across the electrodes 34 and 36. Thus, when a drive voltage is

10 Thus, the liquid crystal molecules 50a and
50b determine the tilting direction of the liquid
crystal molecules in the liquid crystal layer 50 when
a drive voltage is applied to the electrodes 34 and
36. Thereby, the time needed for the entire liquid
15 crystal molecules in the liquid crystal layer 50 to
undergo the tilting is substantially reduced.

As noted above, the pre-tilting of the liquid crystal molecules 50a and 50b effectively reduces the time and magnitude of the electric field necessary for causing the tilting of the entire liquid crystal molecules in the liquid crystal layer 50.

Table 1 below compares the performance of the liquid crystal display device 30 with the performance of a conventional vertically aligned liquid crystal display device in which no such a projection is provided, wherein it should be noted

1 that Table 1 compares the saturation voltage and
response time needed for the liquid crystal display
device to reach a predetermined transmittance.

5 TABLE 1

	saturation voltage	response time [ms] on/off
10 conventional	5.0 V	25/38
1st embodiment	4.3 V	23/37

15 Table 1 clearly indicates the decrease of
the saturation voltage in the present embodiment in
which the projections 38 and 39 are formed over the
conventional device. This means that the voltage
needed for driving the liquid crystal display device
30 is reduced over the conventional device. Further,
20 the response time is improved over the conventional
device. It should be noted that a saturation voltage
is a voltage needed for a liquid crystal display
device to achieve a predetermined transmittance.

25 [SECOND EMBODIMENT]

Next, a liquid crystal display device 31
according to a second embodiment of the present
invention will be described with reference to FIG.6,
wherein those parts corresponding to the parts
30 described previously are designated by the same
reference numerals and the description thereof will be
omitted.

Referring to FIG.6, it can be seen that the
liquid crystal display device 31 has a construction
35 similar to that of the liquid crystal display device
30 of the previous embodiment, except that there is
formed a projection 41 also on the second glass

1 substrate 33.

5 The projection 41 may be formed as a resist pattern prior to the step of forming the molecular alignment film 44 on the substrate 33 such that the projection 41 faces the opposing glass substrate 32. Typically, the resist pattern forming the projection 41 is formed with a height h of about $1.5\ \mu\text{m}$, similarly to the resist patterns forming the projections 38 and 39. After formation of the resist pattern 41, a thermal curing process is applied before providing the molecular alignment film 44. Thereby, the resist pattern 41 undergoes a reflowing to form a bell-shaped projection similarly to the projections 38 and 39. Thereafter, the molecular alignment film 44 is provided on the glass substrate 33 so as to cover the projection 41.

20 By providing the projection 41, the liquid crystal molecules 50c and 50d adjacent to the projection 41 are provided with the pre-tilt angle 51, and the pixel region is divided into a first region 52 located at a first side of the projection 41 and a second region 54 located at a second side of the projection 41. In the first region 52, the direction of tilting of the liquid crystal molecule 50c is generally the same with the direction of tilting of the liquid crystal molecule 50a. Similarly, the direction of tilting of the liquid crystal molecule 50d is generally the same with the direction of tilting of the liquid crystal molecule 50b in the second region 54. Thus, the tilting of the liquid crystal molecules in the liquid crystal layer 50 in the activated state of the liquid crystal display device 31 is substantially facilitated and a further reduction of the drive voltage and a further increase of the response speed are achieved.

35 Table 2 below represents the performance of the liquid crystal display device 31 of the present

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1 embodiment in comparison with the performance of the
conventional vertically aligned liquid crystal display
device noted in Table 1.

5 TABLE 2

	saturation voltage	response time [ms] on/off
10 conventional	5.0 V	25/38
2nd embodiment	3.8 V	20/36

15 As is expected, the liquid crystal display
device 31 of the present embodiment shows a reduced
saturation voltage and increased response speed over
the conventional vertically aligned liquid crystal
display device having no such projections. The result
20 of TABLE 2 further indicates that the addition of the
projection 41 in addition to the projections 38 and 39
further improves the performance of the liquid crystal
display device.

[THIRD EMBODIMENT]

25 FIG.7 shows the construction of a liquid
crystal display device 60 according to a third
embodiment of the present invention.

Referring to FIG.7, the liquid crystal
display device 60 includes a first glass substrate 62
30 carrying thereon electrodes 64 and 66, wherein the
electrodes 64 and 66 carry thereon projections 68 and
69 respectively. Further, the first glass substrate
62 is covered by a molecular alignment film 72 wherein
the molecular alignment film 72 is formed so as to
35 cover the electrodes 64 and 66.

Further, the liquid crystal display device
60 includes a second glass substrate 63 carrying

1 thereon a projection 71, wherein the second glass
substrate 63 including the projection 71 is covered by
a molecular alignment film 74.

5 The first and second substrates 62 and 63
are disposed so as to sandwich a liquid crystal layer
70 therebetween, and polarizers 78 and 77 are disposed
at respective outer-sides of the substrates 62 and 63.

The liquid crystal display device 60 of
FIG.7 is fabricated as follows.

10 First, the electrodes 64 and 66 are formed
on the first substrate 62 by a patterning process of a
conductive layer, and the projections 68 and 69 are
formed respectively on the electrodes 64 and 66 in the
form of a resist pattern. Further, the projection 71
15 is formed on the substrate 63 also in the form of a
resist pattern.

The resist patterns thus formed for the
projections 68 and 69 or the projection 71 are then
subjected to a thermal curing process together with
20 the substrate 62 or 63, wherein the resist patterns
undergo a reflowing during such a thermal curing
process, and the projections 68 and 69 and the
projection 71 are formed to have a bell-shaped form.

After the formation of the projections 68
25 and 69 as mentioned above, the surface of the
substrate 62 carrying the projections 68 and 69 is
covered by the molecular alignment film 72.
Similarly, the surface of the substrate 63 carrying
the projection 71 is covered by the molecular
30 alignment film 74. The substrates 62 and 63 thus
prepared are assembled to form a liquid crystal cell,
and the liquid crystal layer 70 is confined between
the space formed between the substrates 62 and 63.

In the present embodiment, the liquid
35 crystal display device thus fabricated is subjected to
an ultraviolet exposure process similar to that of
FIG.4, wherein the molecular alignment films 72 and 74

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1 are exposed to a ultraviolet radiation before the
substrates 62 and 63 are assembled.

More in detail, the ultraviolet exposure
process is conducted twice, first from a first
5 direction and next from a second, opposite direction
while protecting the right-side part of the projection
71 of the liquid crystal cell by a mask (not shown)
during the first exposure process and while protecting
the left-side part of the projection 71 of the liquid
10 crystal cell by another mask (not shown) during the
second exposure process.

By applying a ultraviolet radiation to the
molecular alignment films 72 and 74 as noted above,
the liquid crystal molecules in the liquid crystal
15 layer 70 are tilted with a tilt angle 76, wherein the
foregoing exposure process is optimized such that the
liquid crystal molecules are tilted in the same
tilting direction of the liquid crystal molecule 70a
or 70c adjacent to the projection 68 or 71 in the
20 left-side part of the projection 71 and such that the
liquid crystal molecules are tilted in the same
tilting direction of the liquid crystal molecule 70b
or 70d adjacent to the projections 69 or 71 in the
right-side part of the projection 71. Thereby, the
25 liquid crystal molecules in the liquid crystal layer
70 at the left-side part of the projection 71
generally have the same tilt angle 76 in a first
tilting direction, while the liquid crystal molecules
at the right-side part of the projection 71 generally
30 have the same tilt angle in the opposite tilting
direction.

By conducting the ultraviolet exposure
process with a dose of about 1.5 J/cm^2 with the angle
of the ultraviolet beam set to 45° as represented in
35 FIG.4, an angle of about 89° is realized for the tilt
angle 76 of the liquid crystal molecules. As the
liquid crystal molecules are thus tilted generally

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1 uniformly in the respective tilting directions
throughout the right-side part or left-side part of
the projection 71 in the liquid crystal layer 70, the
tendency of the liquid crystal molecules to cause a
5 tilting upon application of a driving electric field
to the liquid crystal layer 70 is enhanced further.

Table 3 below represents the saturation
voltage and response time for the liquid crystal
display device 60 of the present embodiment.

10

TABLE 3

	saturation voltage	response time [ms] on/off
15		
	conventional 5.0 V	25/38
	3rd embodiment 4.1 V	22/37

20 As can be seen in Table 3, the liquid
crystal display device 60 of the present embodiment
has the saturation voltage and response time improved
substantially over the conventional vertically aligned
liquid crystal display device.

25 In the present embodiment, there is a
further advantageous feature, associated with the
ultraviolet exposure process, in that such an
ultraviolet radiation reduces the resistance of the
liquid crystal layer 70. More specifically, such a
30 ultraviolet radiation effectively eliminates the
electric charges accumulated between the liquid
crystal layer 70 and the molecular alignment film 72
or 74 and the quality of image representation is
improved.

35

[FOURTH EMBODIMENT]

Next, a liquid crystal display device 80

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1 according to a fourth embodiment of the present
invention will be described with reference to FIG.8.

Referring to FIG.8, the liquid crystal
display device 80 includes a first glass substrate 82
5 carrying thereon electrodes 84 and 86, wherein the
surface of the glass substrate 82 carrying the
electrodes 84 and 86 is covered by a molecular
alignment film 91 including the electrodes 84 and 86.
Further, the liquid crystal display device 80 includes
10 a second glass substrate 83 covered by another
molecular alignment film 92.

The glass substrate 82 and the glass
substrate 83 are assembled such that the surface of
the substrate 82 carrying the molecular alignment film
15 91 faces the surface of the substrate 83 carrying the
molecular alignment film 92, and a liquid crystal
layer 88 is confined in the space formed between the
glass substrates 82 and 83 thus assembled. Further,
there are provided polarizers 93 and 94 at respective
20 outer-sides of the glass substrates 82 and 83.

In the present embodiment, the formation of
projections used in the previous embodiments is
eliminated by selecting the material of the liquid
crystal layer 88. Further, the present embodiment
25 eliminates the process of ultraviolet radiation. More
specifically, the liquid crystal display device 80 of
the present embodiment achieves the desired decrease
of driving voltage and power consumption by optimizing
the material of the liquid crystal layer 88 and the
30 cell structure of the device 80 such that the
retardation value $\Delta n \cdot d$ is maximized.

The simplest answer to increase the
retardation value $\Delta n \cdot d$ would be to increase the cell
thickness d as large as possible. However, such an
35 increase in the cell thickness d tends to invite a
deterioration in the response speed. In order to
increase the retardation value $\Delta n \cdot d$ while

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1 simultaneously suppressing the increase of the cell
thickness d , therefore, it is necessary to choose a
liquid crystal material having a large birefringence
 Δn for the liquid crystal layer 88.

5 The requirement for the birefringence Δn of
the liquid crystal layer 88 is as follows.

In view of the maximum allowable value of
the cell thickness d , which is determined from the
desired response speed of the liquid crystal display
10 device 80, the liquid crystal layer 88 is required to
have a birefringence Δn of larger than about 0.15. On
the other hand, in view of the practical lower limit
value of the cell thickness d of about $3 \mu\text{m}$, which
lower limit value being determined by the fabrication
15 technology used for mass producing the liquid crystal
display device 80, the liquid crystal layer 88 is
required to have a birefringence Δn of smaller than
0.25.

Thus, the liquid crystal material forming
20 the liquid crystal layer 88 should have a
birefringence Δn satisfying the relationship (1)

$$0.15 < \Delta n \cdot d < 0.25. \quad (1)$$

25 The relationship (1) is satisfied by using a
liquid crystal containing a tolan-family component.
Generally, a tolan-family liquid crystal has a low
resistance and is advantageous for dissipating static
electric charges. Thereby, a high-quality image
30 representation free from sticking of the images is
achieved easily.

In the liquid crystal display device 80 of
the present embodiment, a liquid crystal having a
birefringence Δn of 0.202 ($\Delta n = 0.202$) is used in
35 combination with a cell thickness d of $3.5 \mu\text{m}$ ($d = 3.5$
 μm), wherein the liquid crystal has a dielectric
anisotropy $\Delta\epsilon$ of 5.8 ($\Delta\epsilon = 5.8$). In the liquid

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1 crystal device 80, each of the electrodes 84 and 86
has a width W of 5 μm , wherein the electrodes 84 and
86 are separated from each other by a distance L of 12
5 μm . As noted already, the liquid crystal display
device 80 includes no projections. Further, there is
no exposure process to ultraviolet radiation in the
fabrication process of the liquid crystal display
device 80.

10 Table 4 below compares the performance of
the liquid crystal display device 80 thus formed with
the conventional vertically aligned liquid crystal
display device.

TABLE 4

15

	saturation voltage	response time [ms] on/off
conventional	5.0 V	25/38
20 4th embodiment	5.1 V	15/20

Referring to Table 4, it can be seen that
the response time is reduced substantially over any of
25 the conventional device or the device of first through
third embodiments, wherein the result of Table 4
indicates that the use of the liquid crystal having a
large birefringence larger than in any of the
foregoing first through third embodiments improves the
30 voltage response characteristic with regard to the
tilting of the liquid crystal molecules.

[FIFTH EMBODIMENT]

FIG.9 shows the construction of a liquid
35 crystal display device 100 according to a fifth
embodiment of the present invention, wherein the
liquid crystal display device 100 has a construction

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1 similar to that of the liquid crystal display device
80 of the previous embodiment except that projections
96 and 98 are respectively provided on the electrodes
84 and 86. In FIG.9, those parts corresponding to the
5 parts described previously are designated by the same
reference numerals and the description thereof will be
omitted.

Table 5 below represents the saturation
voltage and response time for the liquid crystal
10 display device 100 of the present embodiment in
comparison with the conventional vertically aligned
liquid crystal display device.

TABLE 5

15		saturation voltage	response time [ms] on/off
	conventional	5.0 V	25/38
20	5th embodiment	4.3 V	9/15

Referring to Table 5, it can be seen that
both the saturation voltage and response time are
25 improved substantially over the conventional device.
Particularly, the improvement of response time is
remarkable. The result of Table 5 indicates that the
combination of the construction of the embodiment of
FIG.8 with the feature of the projections in the first
30 embodiment is highly effective for reducing the
electric power consumption of the liquid crystal
display device.

Further, the present invention is not
limited to the embodiments described heretofore, but
35 various variations and modifications may be made
without departing from the scope of the present
invention.

1 WHAT IS CLAIMED IS

5

1. A liquid crystal display device,
comprising:

a first substrate;

10 a second substrate facing said first
substrate;

a liquid crystal layer interposed between
said first and second substrates; and

15 a group of electrodes disposed on said first
substrate so as to create an electric field in said
liquid crystal layer generally parallel to said first
substrate in an activated state in which a drive
voltage is applied to said group of electrodes;

20 said liquid crystal molecules aligning
generally perpendicularly to a plane of said first
substrate in a non-activated state in which said drive
voltage is not applied to said group of electrodes,
said liquid crystal molecules aligning generally
parallel to said plane of said first substrate in said
activated state;

25 said liquid crystal molecules having a pre-
tilt angle of less than 90° in at least one of a part
of said liquid crystal layer corresponding to a pixel
and said electrode on said first substrate.

30

2. A liquid crystal display device as
claimed in claim 1, wherein said electrodes include a
35 first electrode provided on a surface of said first
substrate facing said second substrate and a second
electrode provided on said surface with a separation

1 from said first electrode, and wherein said liquid
crystal display device further includes a first
projection provided on said first electrode and a
5 said first and second projections inducing said pre-
tilt angle in said liquid crystal molecules locating
adjacent to said first and second projections.

10

3. A liquid crystal display device as
claimed in claim 2, further including a third
projection on a surface of said second substrate
15 facing said first substrate.

20 4. A liquid crystal display device,
comprising:
a first substrate;
a second substrate facing said first
substrate;
25 a liquid crystal layer interposed between
said first and second substrates; and
a group of electrodes disposed on said first
substrate so as to create an electric field in said
liquid crystal layer generally parallel to said first
30 substrate in an activated state in which a drive
voltage is applied to said group of electrodes;
said liquid crystal molecules aligning
generally perpendicularly to a plane of said first
substrate in a non-activated state in which said drive
35 voltage is not applied to said group of electrodes,
said liquid crystal molecules aligning generally
parallel to said plane of said first substrate in said

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1 activated state;
 said liquid crystal layer having a
birefringence larger than about 0.10 but smaller than
about 0.25.

5

5. A liquid crystal display device as
10 claimed in claim 4, wherein said liquid crystal layer
contains a tolan-family component.

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1 ABSTRACT OF THE DISCLOSURE

 A vertically aligned liquid crystal display
device includes a site in a liquid crystal layer in
which liquid crystal molecules are tilted in a
5 predetermined direction in a non-activated state of
the liquid crystal display device.

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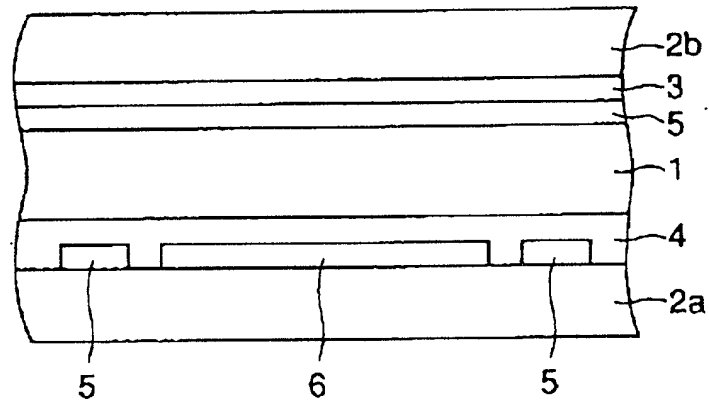
05282772.033499

【書類名】 図面

【図1】

FIG 1
PRIOR ART

第1の従来例による液晶表示パネル断面を示す図



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【図 2】

第2の従来の例による液晶表示パネル断面を示す図

FIG 2A
PRIOR ART

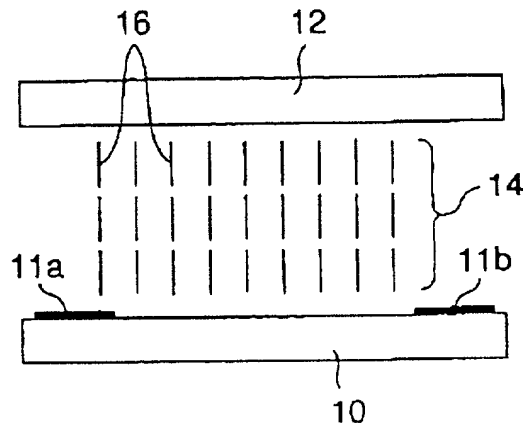
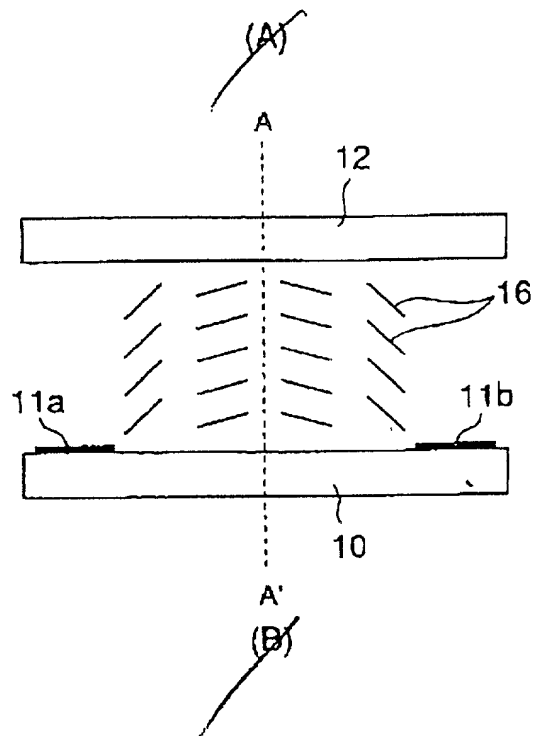


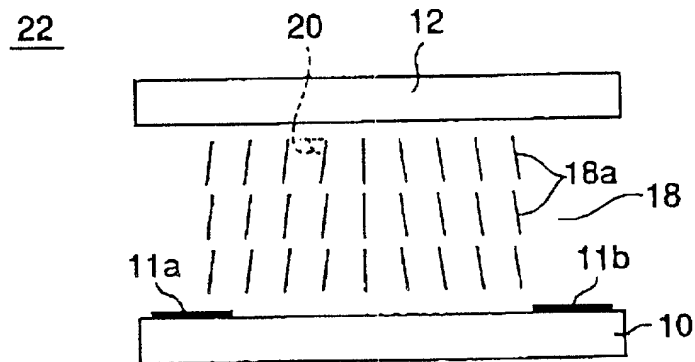
FIG 2B
PRIOR ART



【図3】

FIG 3

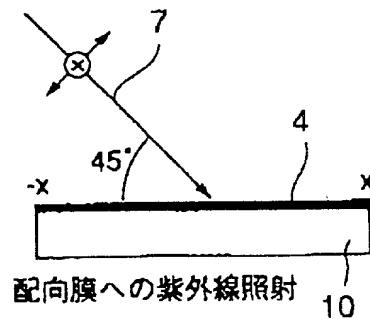
本発明における液晶表示パネルの基本概念を示す図（その1）



【図4】

FIG 4

本発明における液晶表示パネルの基本概念を示す図（その2）

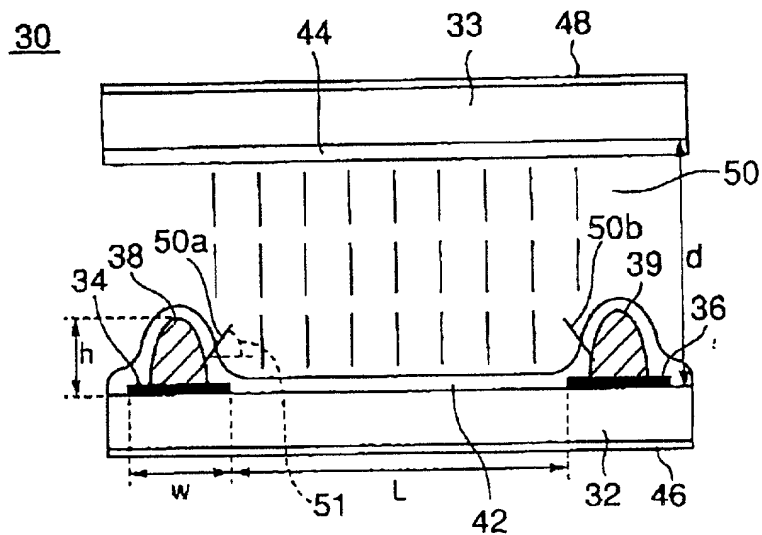


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【図5】

FIG 5

本発明における液晶表示パネルの第1の実施例を示す図

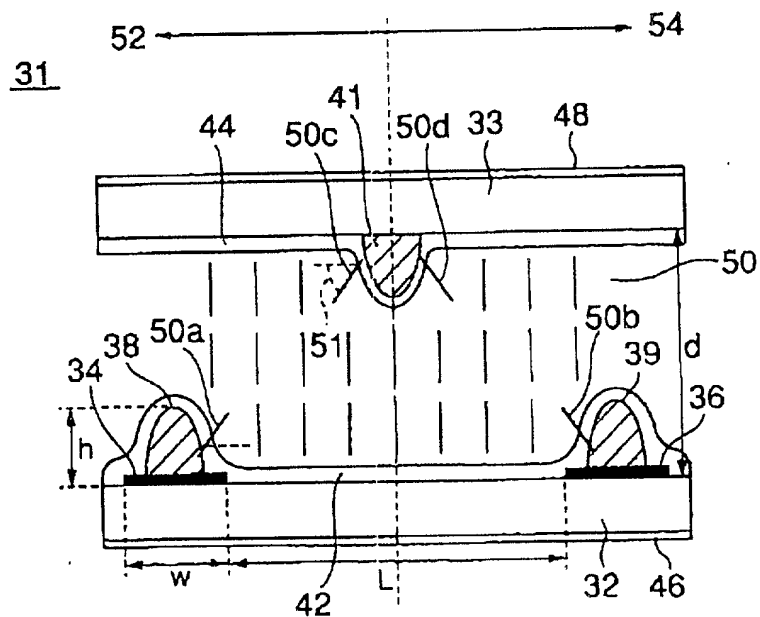


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【図6】

FIG 6

本発明における液晶表示パネルの第2の実施例を示す図

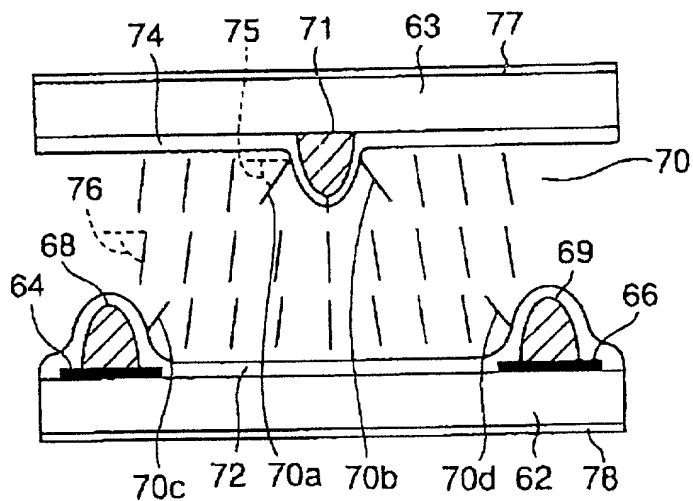


【図7】

FIG 7

本発明における液晶表示パネルの第3の実施例を示す図

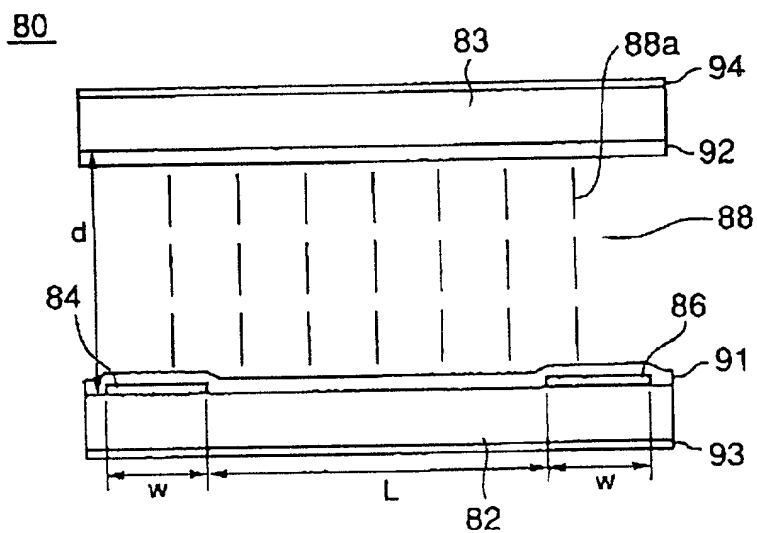
60



【図8】

FIG 8

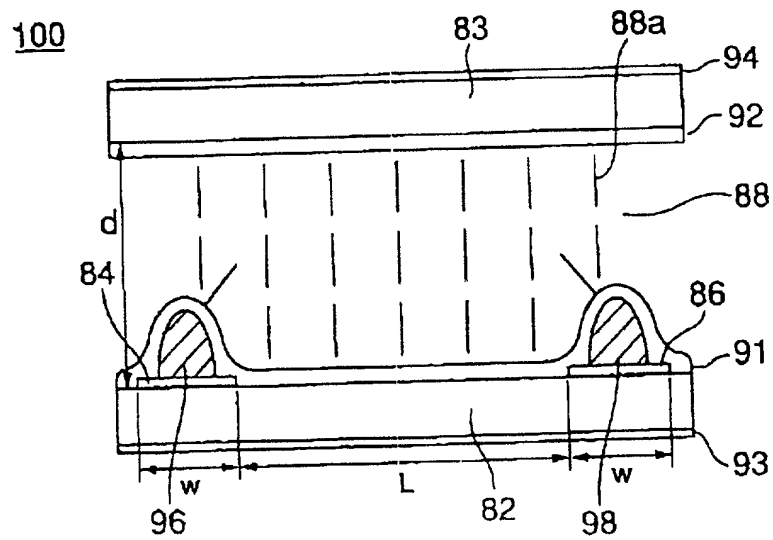
本発明における液晶表示パネルの第4の実施例を示す図



【図9】

FIG 9

本発明における液晶表示パネルの第5の実施例を示す図



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Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して特許範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

LIQUID CRYSTAL DISPLAY DEVICE

OPERATING IN A VERTICALLY ALIGNED
MODE OF LIQUID CRYSTAL MOLECULES

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ 月 日に提出され、米国出願番号または特許協定条約
国際出願番号を _____ とし、
(該当する場合) _____ に訂正されました。

☐ was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
_____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、
内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of
the above identified specification, including the claims, as
amended by any amendment referred to above.

私は、連邦規則法典第37章第1条56項に定義されると
おり、特許資格の有無について重要な情報を開示する義務が
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I acknowledge the duty to disclose information which is material to
patentability as defined in Title 37, Code of Federal Regulations,
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Japanese Language Declaration (日本語宣言書)

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基づき下記の、米国外の国の少なくとも一カ国を指定している特許協力条約365(a)項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している。本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

Prior Foreign Application(s)
外国での先行出願

Pat. Appln. No.10-263578	Japan
(Number) (番号)	(Country) (国名)
_____	_____
(Number) (番号)	(Country) (国名)
_____	_____

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Not Claimed
優先権主張なし

17/September/1998	<input type="checkbox"/>
(Day/Month/Year Filed) (出願年月日)	

(Day/Month/Year Filed) (出願年月日)	<input type="checkbox"/>

私は、第35編米国法典119条(e)項に基づいて下記の米国外特許出願規定に記載された権利をここに主張いたします。

(Application No.) (出願番号)	(Filing Date) (出願日)
_____	_____

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)
_____	_____

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(Application No.) (出願番号)	(Filing Date) (出願日)
_____	_____

(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)

(Application No.) (出願番号)	(Filing Date) (出願日)
_____	_____

(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)

私は、私自身の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じることに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の表明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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		Japan	
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国籍		Citizenship	
郵便所		Post Office Address	
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住所		Residence	
国籍		Citizenship	
郵便所		Post Office Address	

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